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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION TO DETERMINE SOME EFFECTS OF TAIL DAMPING AND WING-TAIL INTERFERENCE ON THE ROLLING EFFECTIVENESS OF AILERONS AND A SPOILER ON A MODIFIED-DELTA WING AT MACH NUMBERS FROM 0.6 TO 1.5

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

May 10, 1957

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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION TO DETERMINE SOME EFFECTS OF TAIL DAMPING AND WING-TAIL INTERFERENCE ON THE ROLLING EFFECTIVENESS OF AILERONS AND A SPOILER ON A MODIFIED-DELTA WING AT MACH NUMBERS FROM 0.6 TO 1.5

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SUMMARY

An investigation has been made to determine some effects of tail damping and wing-tail interference on the rolling effectiveness of ailerons and a spoiler on a modified-delta wing. The investigation was made by means of free-flight models at 0° angle of attack and 0° angle of sideslip over a range of Mach numbers from 0.6 to 1.5. The results indicate that adding tail surfaces to a wing-body combination appreciably reduced the rolling effectiveness of a 1/3-exposed-span inboard aileron, a 2/3-exposed-span inboard aileron, and a 2/3-exposed-span inboard spoiler, but caused negligible change in the rolling effectiveness of a 1/3-exposed-span midspan aileron. Changing the location of the horizontal tail from the plane of the wing to 40 percent of the wing root chord above the plane of the wing caused a further reduction in the rolling effectiveness of the 2/3-exposed-span aileron at subsonic speeds and the 2/3-exposed-span spoiler at both subsonic and supersonic speeds.

INTRODUCTION

The importance of including the effects of tail damping and wing-tail interference in investigations of rolling effectiveness of lateral controls has been shown previously in reference 1. The data of reference 1 were limited to ailerons, however, and were limited as to the tail locations investigated in an effort to alleviate the effects of downwash also. It is the purpose of this investigation to determine some effects of tail damping and wing-tail interference on the rolling effectiveness of both ailerons and spoilers and to determine the effect of moving the

horizontal tail from the plane of the wing to an appreciable distance above the plane of the wing. The investigation was made at 0° angle of attack and 0° angle of sideslip over a range of Mach numbers from 0.6 to 1.5.

SYMBOLS

b	wing span, ft
c	wing chord, ft
c_r	wing root chord at body center line, 1.416 ft
M	Mach number
p	rolling velocity, radians/sec
R	Reynolds number
V	velocity of model along flight path, ft/sec
pb/2V	wing-tip helix angle, radians
$\Delta(pb/2V)$	change in pb/2V due to a change in model geometry

DESCRIPTION OF MODELS

The models of this investigation consisted of modified-delta wings on cylindrical bodies with ogive noses and with tails which were free to roll relative to the body so as to provide longitudinal and directional stability without causing resistance to roll. The wings had an aspect ratio of 3.150, a semispan of 1.114 feet, and were swept back 55° at the leading edge and 10° at the trailing edge. Seven of the models were equipped with plain, trailing-edge ailerons differentially deflected. The deflection of each aileron was 5°. Three models were equipped with spoilers located 0.375 inch forward of the trailing edge. The aileron chord was $0.100c_r$ and the spoiler height was $0.022c_r$.

In order to determine the effect of adding tail surfaces to the configuration, six of the models were equipped with fixed horizontal and vertical tail surfaces of the same plan form as the wing. The area of the horizontal tail was 25 percent of the wing area and the semispan was one-half the wing semispan. The area of the vertical tail was 25 percent of the wing area and the height of the vertical tail was 70.7 percent of

the wing semispan. On four models the horizontal tail was located in the plane of the wing. On two of the models the horizontal tail was located $0.400c_r$ above the plane of the wing. It should be noted that the free-to-roll tails mentioned previously had negligible resistance to roll; the models without fixed tail surfaces were, therefore, effectively wing-body combinations and are herein after referred to as models with no tails.

The wings of the models were machined from solid aluminum alloy and had an NACA 65A003 airfoil section. The tail surfaces were of 1/8-inch aluminum-alloy flat plate with rounded leading edges. The physical characteristics and dimensions of the models are given in tables I and II and in the photographs of figure 1 and in the sketches of figure 2.

TESTS

The tests were made at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. A two-stage rocket was used to propel the models to a Mach number of about 1.5. Test data were recorded continuously during a period of free flight following burnout of the second propulsion stage. A spinsonde (polarized radio transmitter) was used to measure rolling velocity. Model flight-path velocity, range, and altitude were measured by means of radar. Atmospheric data and wind velocity were obtained just prior to each test by means of radio equipment carried aloft by balloons which were tracked by radar. The range of test Reynolds numbers is shown in figure 3.

ACCURACY AND CORRECTIONS

It is estimated that the test data are accurate within the following limits:

	Subsonic	Supersonic
$pb/2V$, radians	±0.003	±0.001
M	±0.01	±0.01

The data were corrected by the method of reference 2 for the wing and tail incidence errors resulting from construction tolerances. No correction was made for the effects of rolling moment of inertia since, at the rolling accelerations incurred in these tests, reference 3 shows these effects to be negligible.

REFERENCES

1. English, Roland D.: Free-Flight Investigation To Determine Some Effects of Tail Damping and Wing-Tail Interference on the Rolling Effectiveness of Inboard and Outboard Ailerons on an Untapered Sweptback Wing. NACA RM L54L17a, 1955.

2. Strass, H. Kurt, and Marley, Edward T.: Rolling Effectiveness of All-Movable Wings at Small Angles of Incidence at Mach Numbers From 0.6 to 1.6. NACA RM L51H03, 1951.

3. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds To Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM L7D02, 1947.

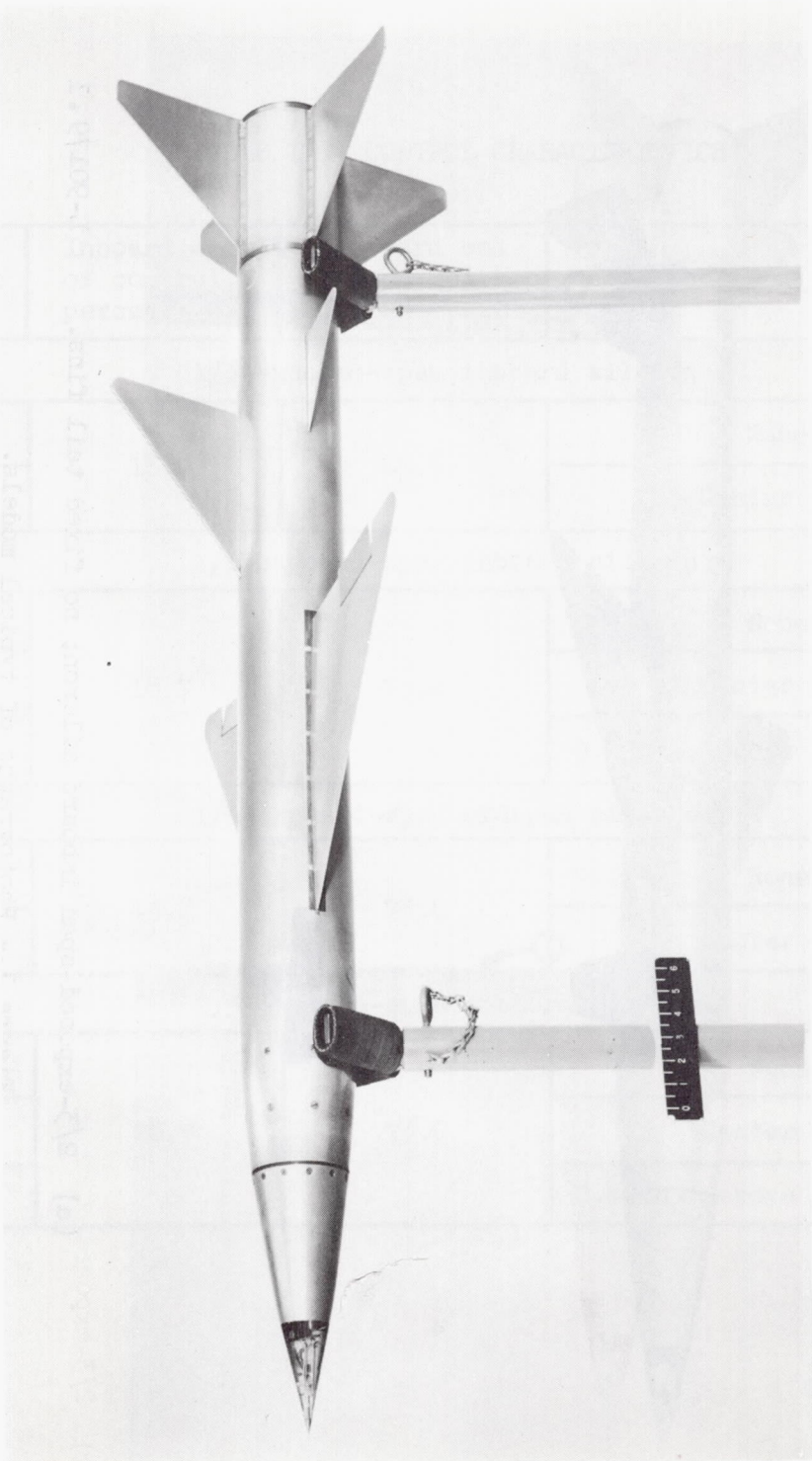
4. Spreiter, John R.: The Aerodynamic Forces on Slender Plane- and Cruciform-Wing and Body Combinations. NACA Rep. 962, 1950. (Supersedes NACA TN's 1897 and 1662.)

5. Diederich, Franklin W.: Charts and Tables for Use in Calculations of Downwash of Wings of Arbitrary Plan Form. NACA TN 2353, 1951.

6. Mirels, Harold, and Haefeli, Rudolph C.: Line-Vortex Theory for Calculation of Supersonic Downwash. NACA Rep. 983, 1950.

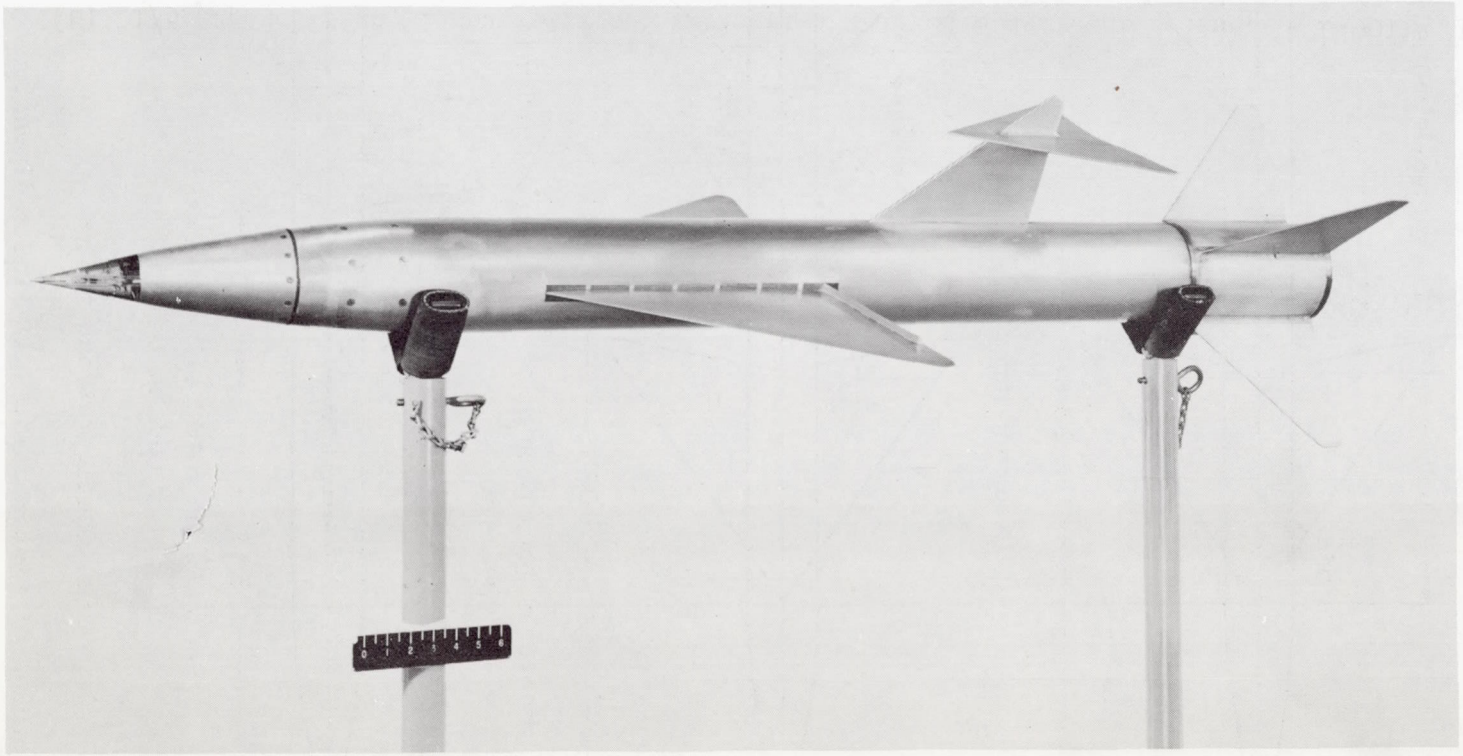
TABLE I.- MODEL PHYSICAL CHARACTERISTICS

Body:	
Diameter, in.	5.00
Length, in.	63.87
Fineness ratio	12.77
Wing:	
Span, in.	26.74
Chord at center line, in.	16.98
Area, sq in.	227.02
Aspect ratio	3.15
Sweep angle, leading edge, deg	55.00
Sweep angle, trailing edge, deg	10.00
Thickness ratio	0.03
Aileron:	
Chord, in.	1.70
Spoiler:	
Height, in.	0.38
Horizontal tail:	
Span, in.	13.37
Chord at center line, in.	8.49
Area, sq in.	56.80
Aspect ratio	3.15
Sweep angle, leading edge, deg	55.00
Sweep angle, trailing edge, deg	10.00
Thickness, in.	0.13
Vertical tail:	
Height, in.	9.45
Chord at center line, in.	12.00
Area, sq in.	56.80
Aspect ratio	3.15
Sweep angle, leading edge, deg	55.00
Sweep angle, trailing edge, deg	10.00
Thickness, in.	0.13



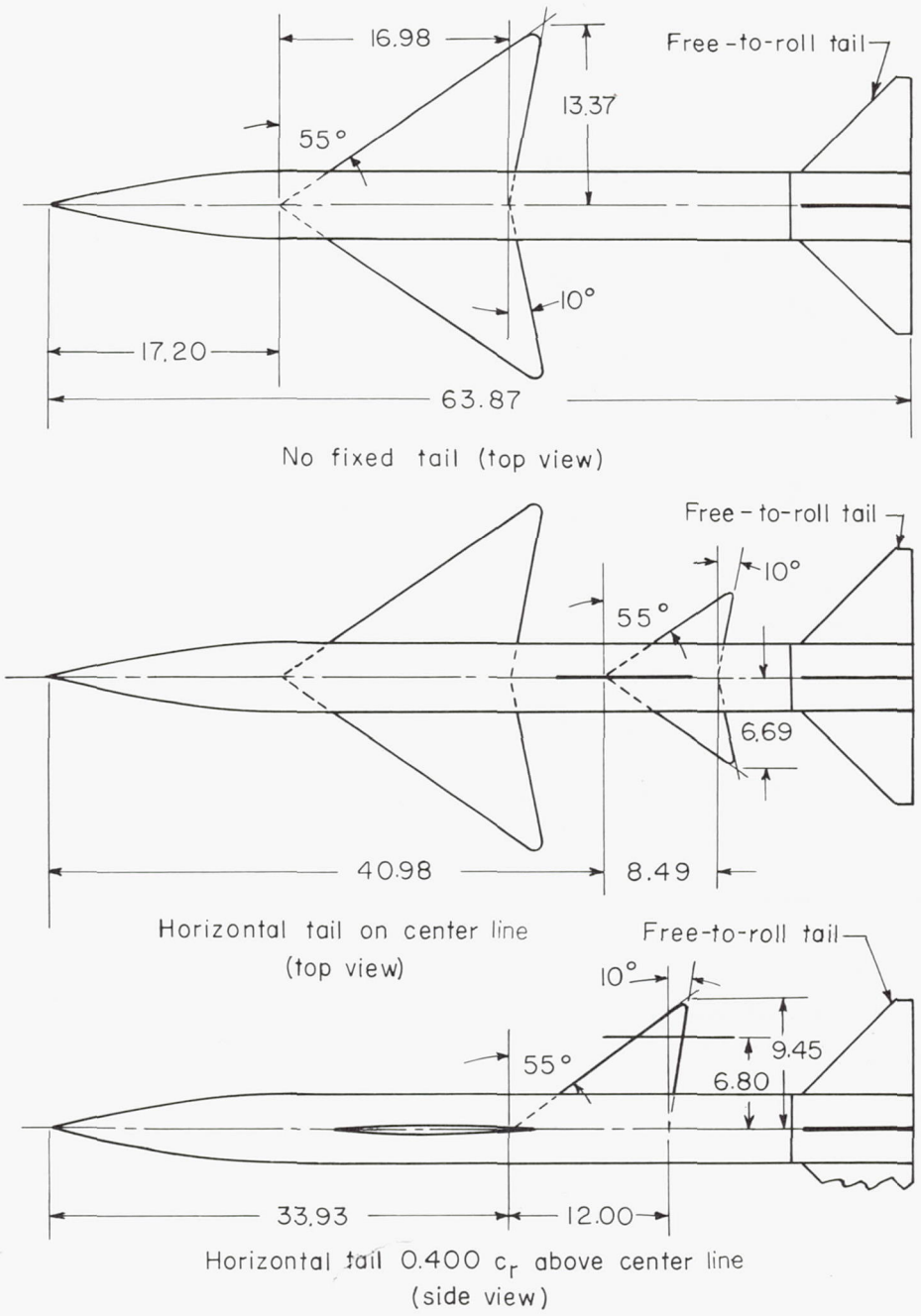
(b) 1/3-exposed-span midspan aileron; horizontal tail on model center line. L-90114.1

Figure 1.- Continued.



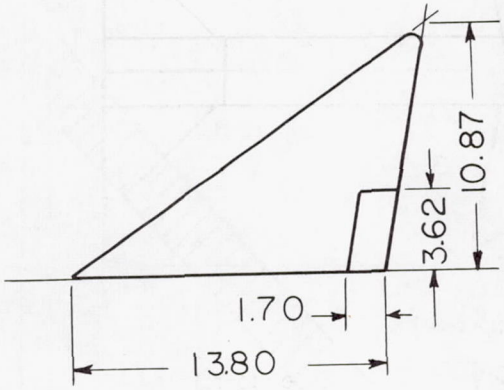
(c) 2/3-exposed-span inboard spoiler; horizontal tail $0.400c_r$ above center line. L-90116.1

Figure 1.- Concluded.

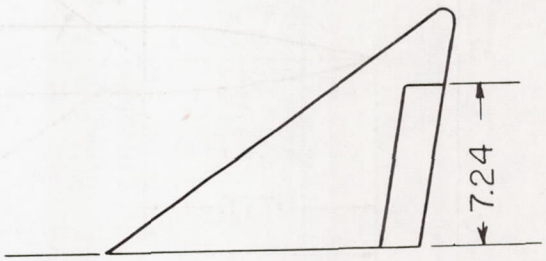


(a) Configurations tested.

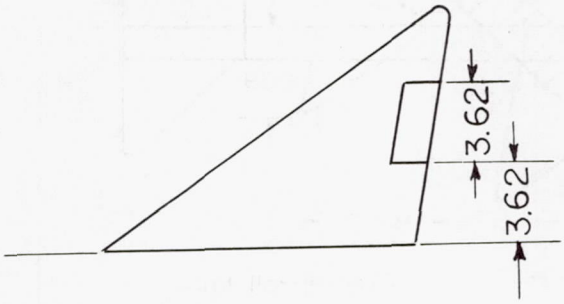
Figure 2.- Sketches of test models. All linear dimensions in inches.



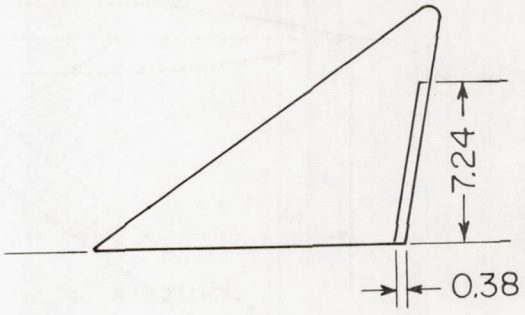
1/3-exposed-span inboard aileron



2/3-exposed-span inboard aileron



1/3-exposed-span midspan aileron



2/3-exposed-span inboard spoiler

(b) Control details.

Figure 2.- Concluded.

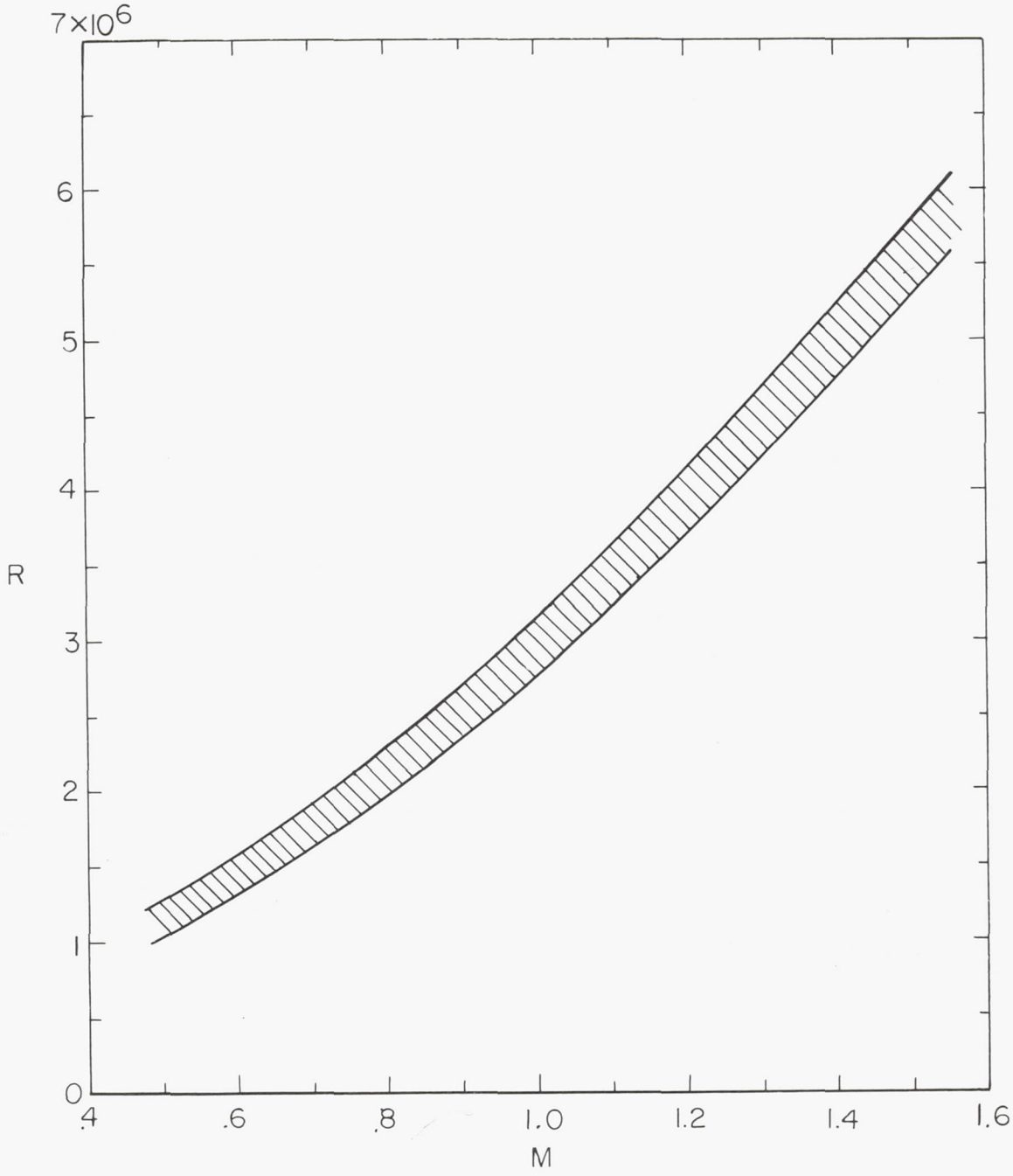
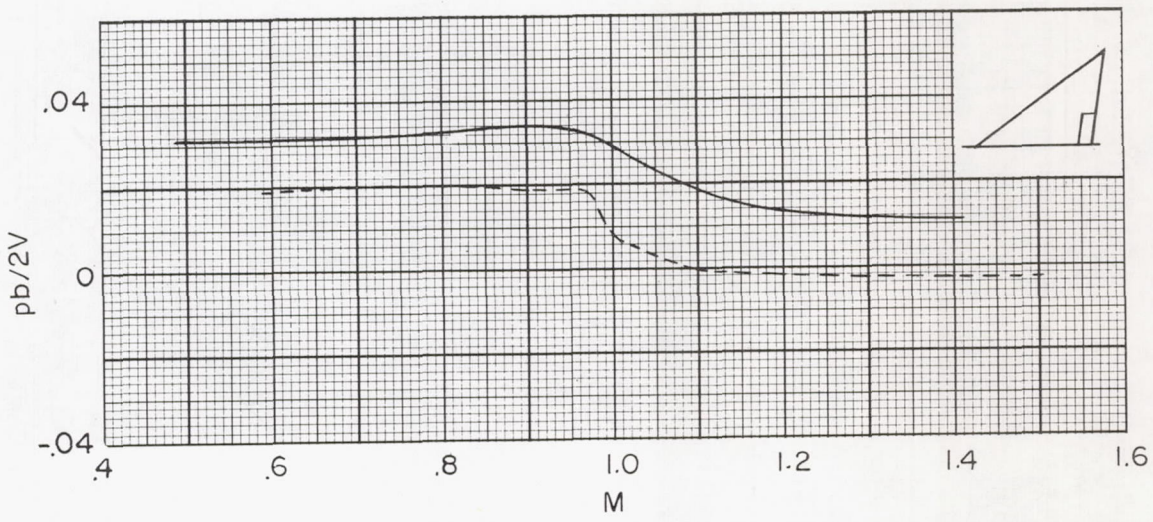
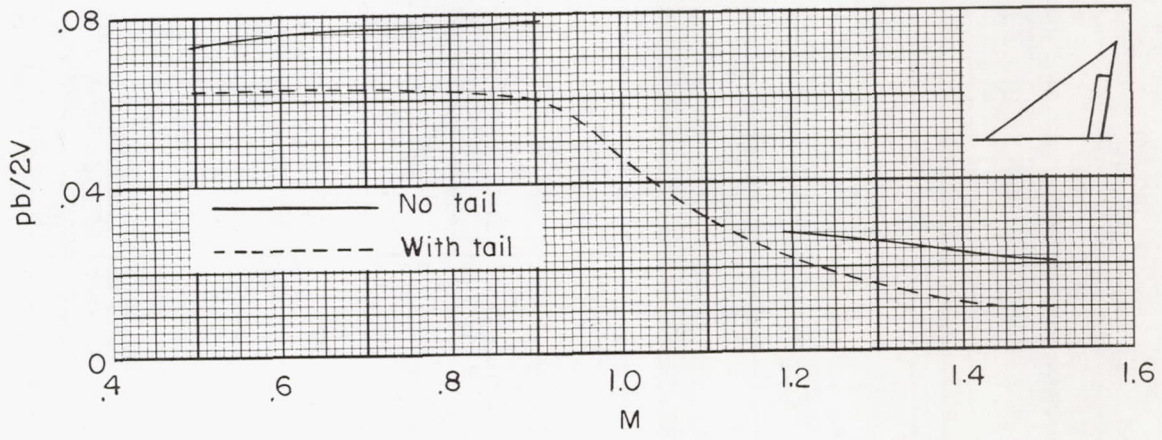


Figure 3.- Variation of Reynolds number with Mach number. Reynolds number based on mean exposed wing chord, 0.575 foot.

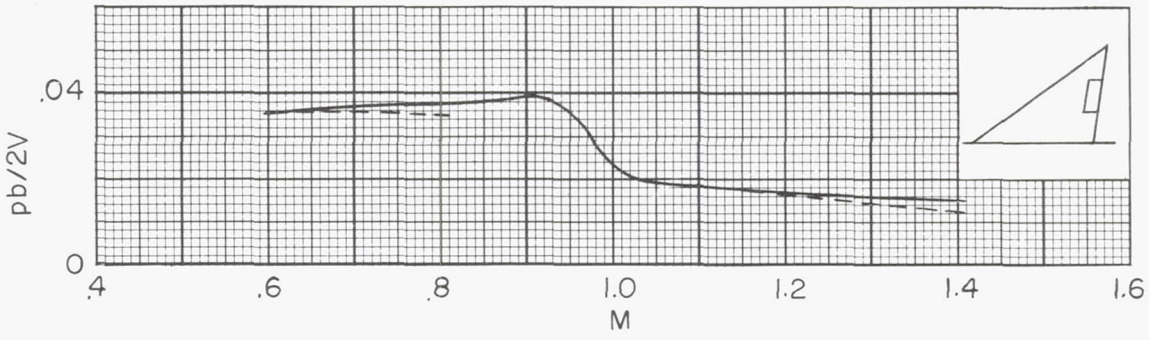


(a) 1/3-exposed-span inboard aileron.

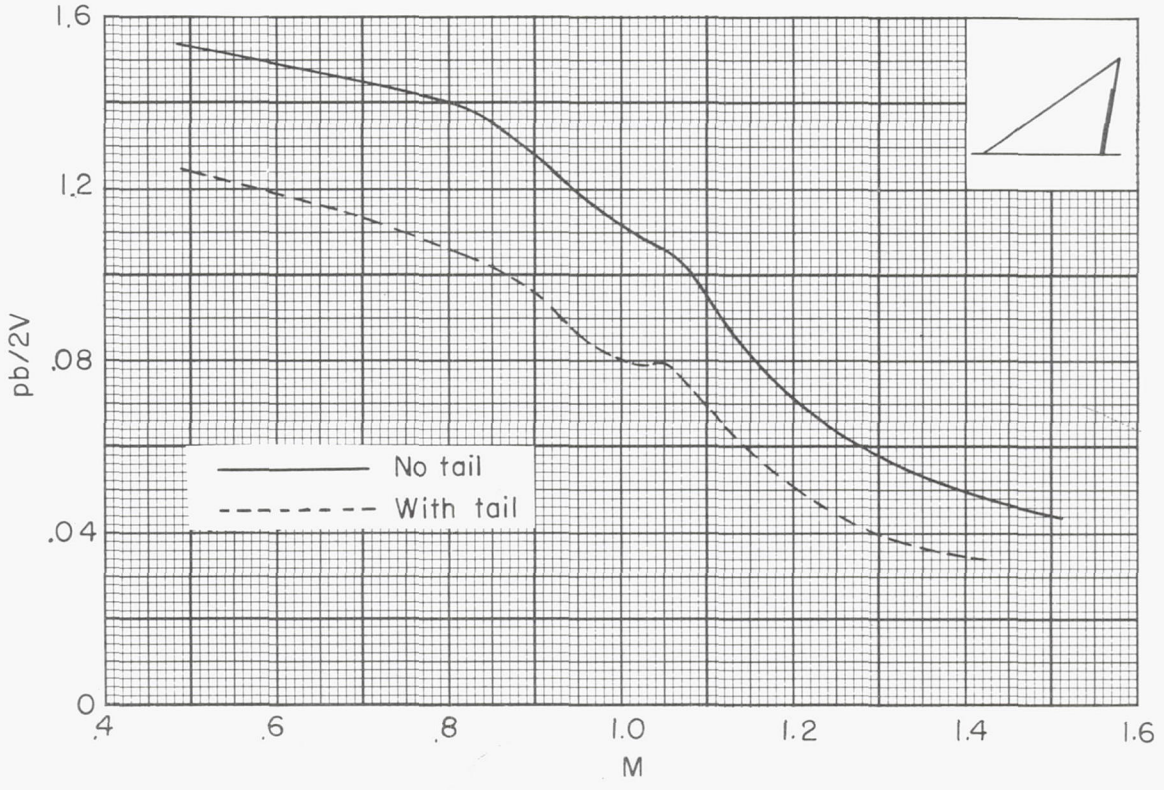


(b) 2/3-exposed-span inboard aileron.

Figure 4.- Effect on pb/2V of adding fixed tail surfaces to the configuration.

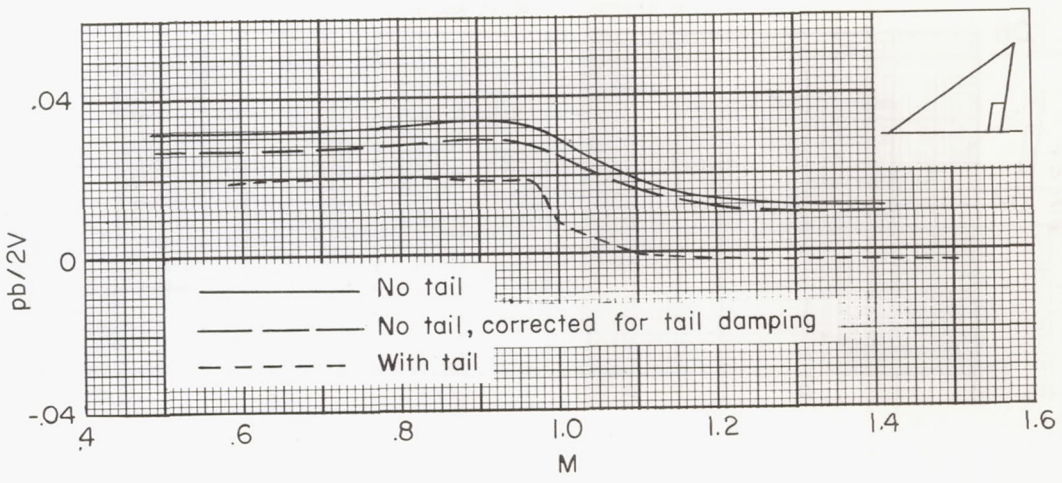


(c) 1/3-exposed-span midspan aileron.

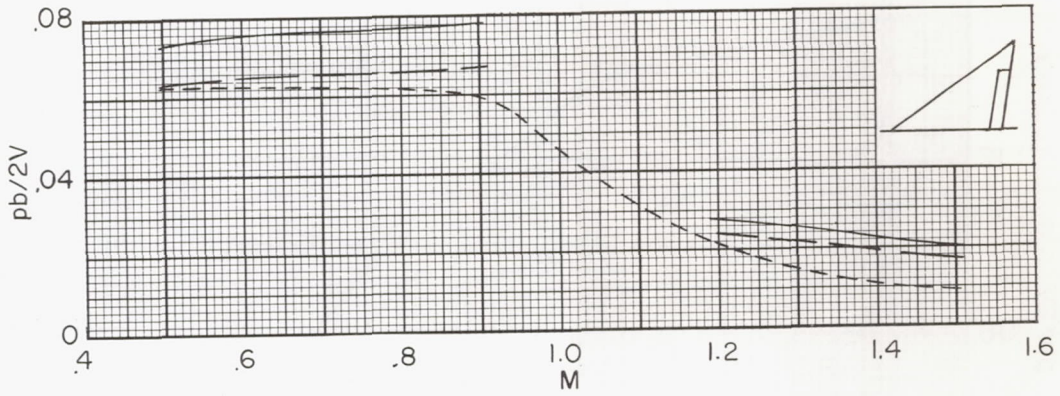


(d) 2/3-exposed-span inboard spoiler.

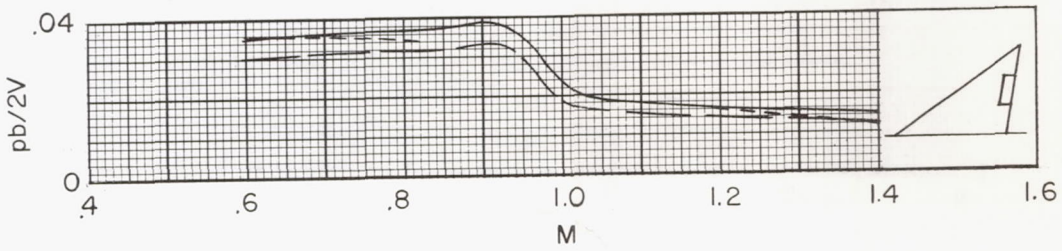
Figure 4.- Concluded.



(a) 1/3-exposed-span inboard aileron.

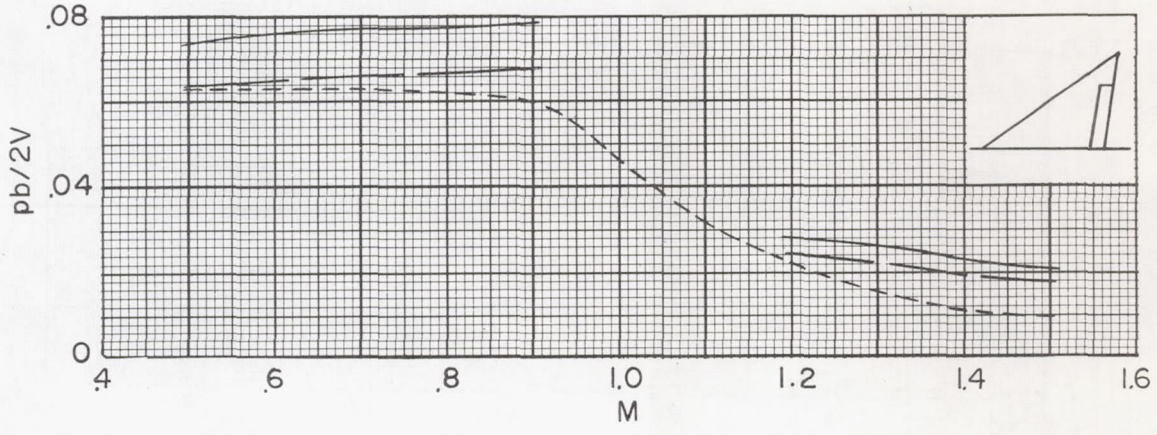


(b) 2/3-exposed-span inboard aileron.

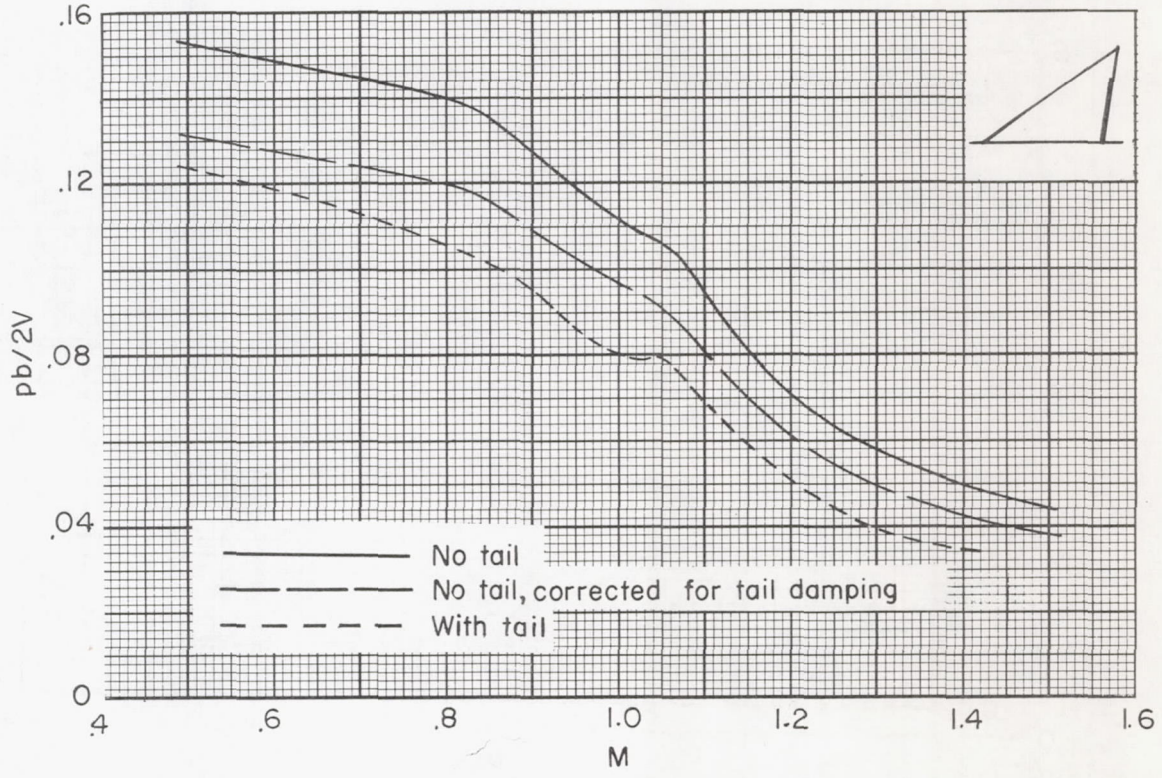


(c) 1/3-exposed-span midspan aileron.

Figure 5.- Comparison of reduction in pb/2V due to wing-tail interference for the various ailerons.

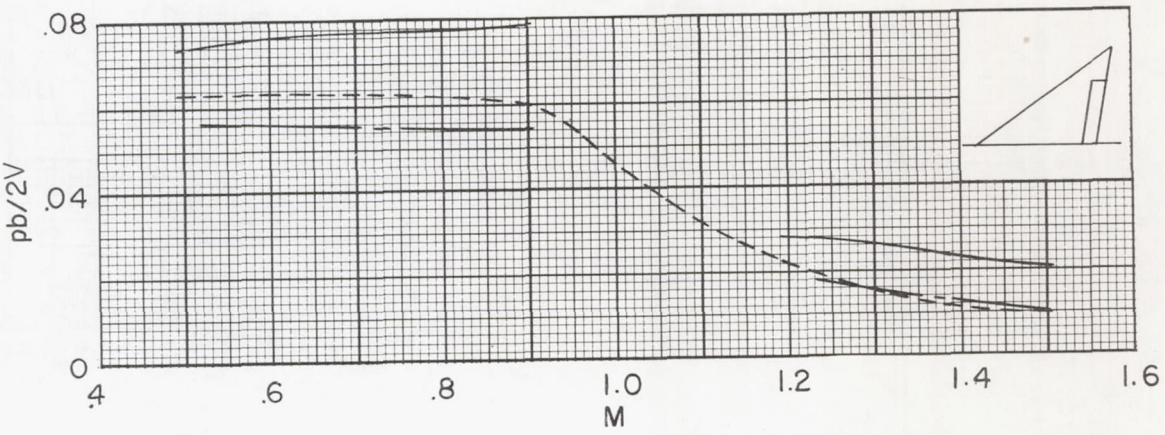


(a) 2/3-exposed-span inboard aileron.

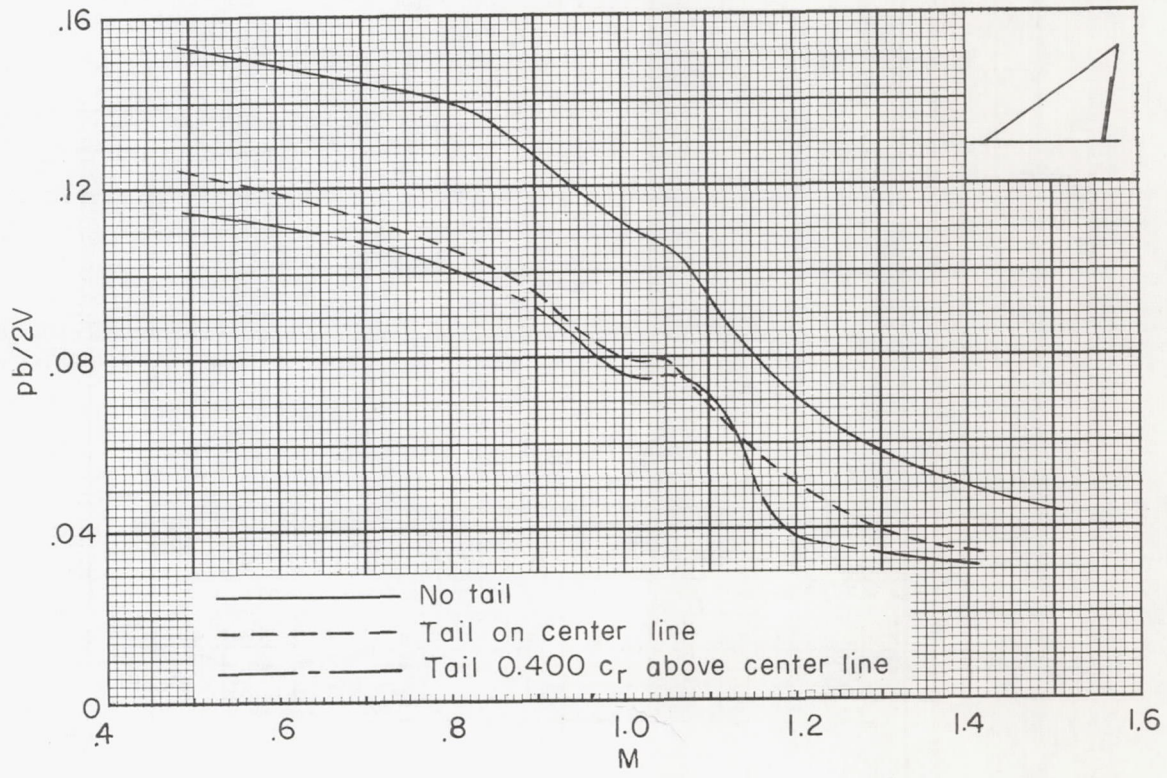


(b) 2/3-exposed-span inboard spoiler.

Figure 6.- Comparison of wing-tail interference for an aileron and a spoiler.

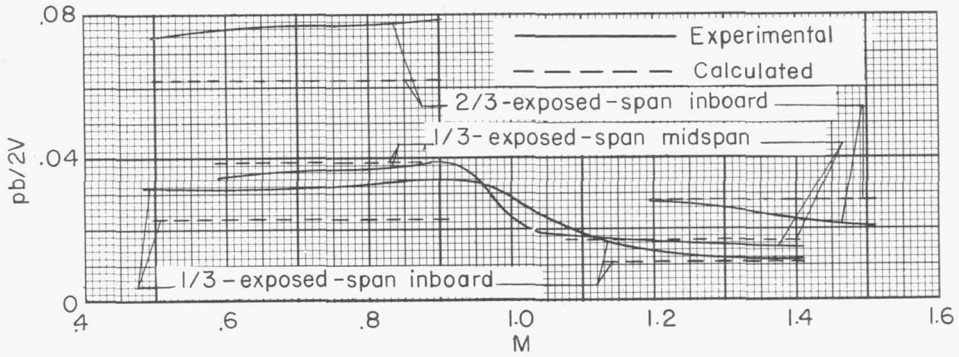


(a) 2/3-exposed-span inboard aileron.

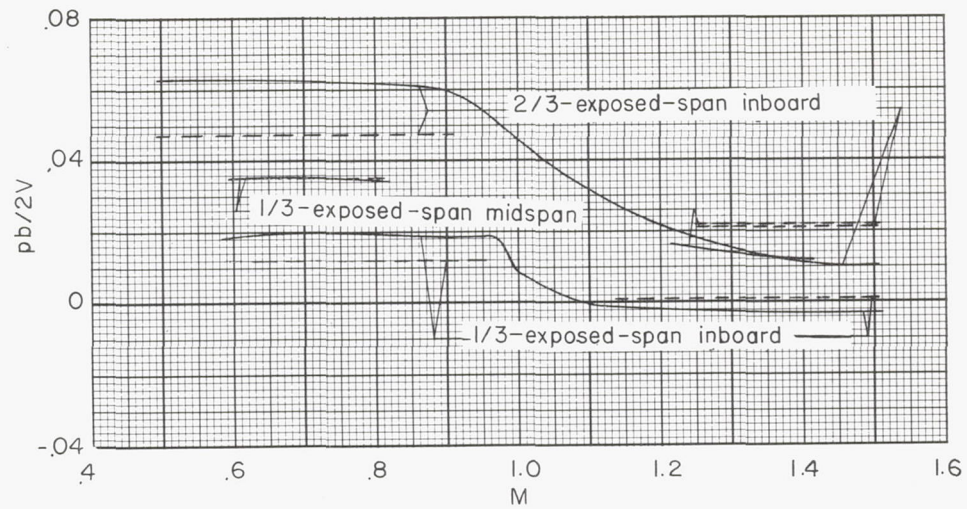


(b) 2/3-exposed-span inboard spoiler.

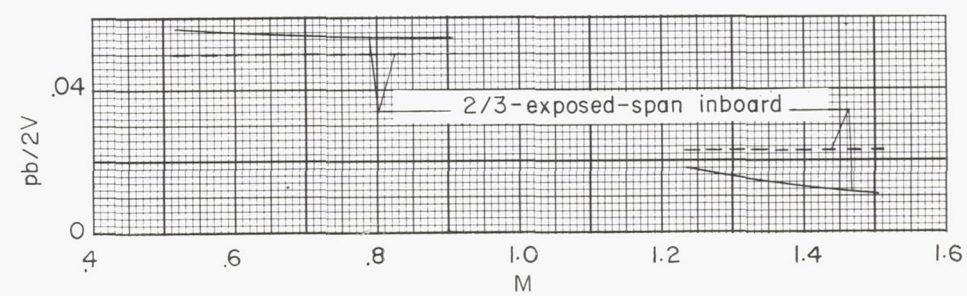
Figure 7.- Effect of raising the horizontal tail 0.400c_r above the center line.



(a) No tail.

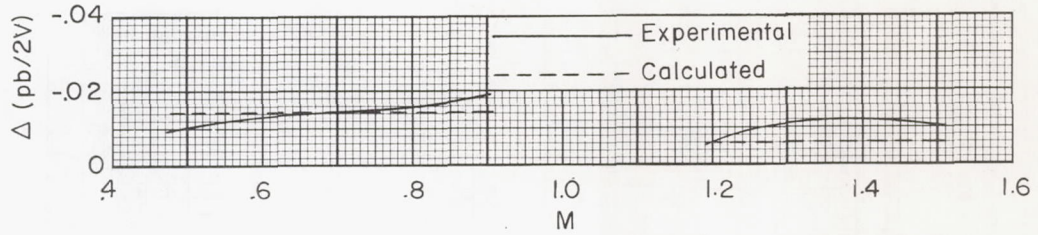


(b) Tail on center line.

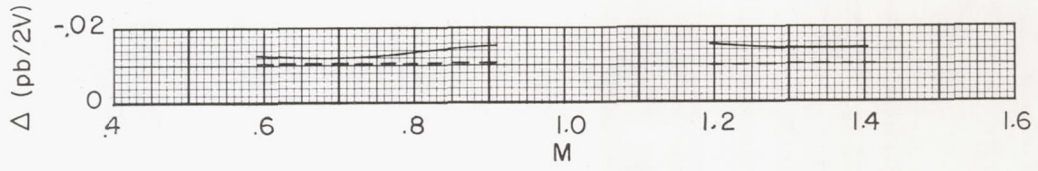


(c) Tail $0.400c_r$ above center line.

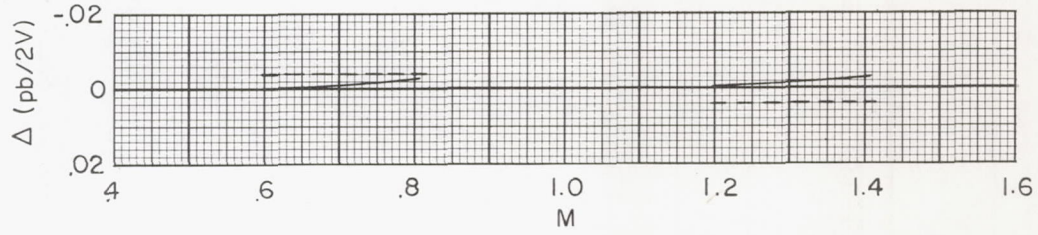
Figure 8.- Comparison of calculated and experimental data.



2/3-exposed-span inboard aileron

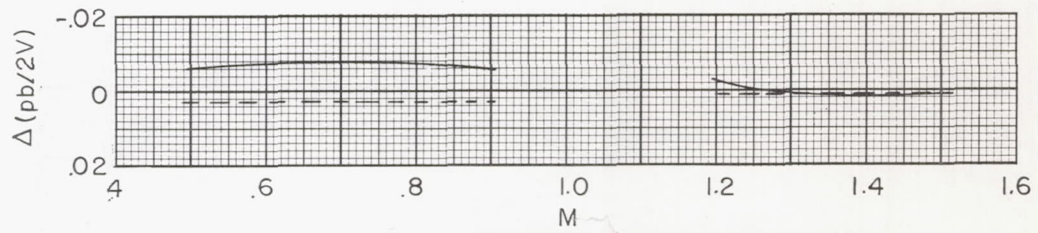


1/3-exposed-span inboard aileron



1/3-exposed-span midspan aileron

(a) Δ(pb/2V) due to addition of tail surfaces.



2/3-exposed-span inboard aileron

(b) Δ(pb/2V) due to changing horizontal-tail location.

Figure 9.- Variation of change in pb/2V due to addition of tail surfaces and due to change in horizontal-tail location with Mach number.

NACA - Langley Field, Va.